Entire surface covered by small, triangular, imbricating scales, decreasing in size towards the lateral margins; along the anterior portion of the carapace the scales are not visible. The paletti (one of which is preserved) long and narrow, being nearly twice as long as wide, and has the characteristic serrated margin, which is the principal distinguishing feature in the sub-genus. Length of specimen, without terminal joint, two and three-fourths inches; greatest breadth seven-eighths of an inch.

Position and locality. Found in the shale immediately below the Darlington cannel coal, near Cannelton, Darlington Township, Beaver Co. Pennsylvania. Horizon, Alleghany River Series.

We are indebted to Mr. S. F. Mansfield, of Cannelton, for this beautiful specimen, and after whom we deem it proper to name the species.

On the Relative Ages of the Sun and certain of the Fixed Stars.

By Professor Daniel Kirkwood, of Indiana University.

(Read before the American Philosophical Society, April 6, 1877.)

The doctrine that the light and heat of the sun are produced by the chemical combination of its elements was very generally accepted till about the middle of the nineteenth century. It has, however, been completely disproved by the labors of Dr. Mayer and Sir William Thomson. The quantity of heat radiated by the sun in a given unit of time has been determined with approximate accuracy. The amount produced by the combustion of a given quantity of coal is also known. From these data it is easily shown that if the sun were a solid globe of coal, and a sufficient supply of oxygen were furnished to support its combustion, the amount of heat resulting from its consumption would be less than that actually emitted within historic times. "Take (in mass equal to the sun's mass) the most energetic chemicals known to us, and in the proper proportion for giving the greatest amount of heat by actual chemical combination; and, so far as we yet know their properties, we cannot see the means of supplying the sun's present waste for even 5,000 years."* The chemical theory is accordingly given up as wholly untenable.

What then is the source of solar energy? To this interesting question, in the present state of our knowledge, but one reply is possible. The great law of the conservation of force—one of the most important discoveries in the history of physical science—points at once to a cause which is adequate both in mode and measure. Motion may be transformed into heat, and *vice versa*. The heat produced by the fall of a given quantity of matter upon the sun from the outer limits of the solar system would be 7,000 times greater than that resulting from the combustion of its own weight of coal. In the mechanical theory of solar energy, as advocated by Helmholtz and

* Tait's Recent Advances in Physical Science, 2nd Ed. p. 152.

now generally accepted, the sun's heat is produced by the falling together or condensation of the matter of which its mass is composed. But the rate of solar radiation and also the mechanical equivalent of heat are known. With these as data it may be easily calculated that a contraction of the sun's radius amounting to one mile in 40 years would be sufficient to keep up the present supply of heat. At former epochs, when the volume was greater and the density less, a more rapid contraction was necessary to keep up the supply. If the sun, or rather the solar system originally existed as a nebulous mass, with a radius equal to half the distance of the nearest fixed stars, the total amount of heat generated by contracting to its present dimensions would have kept up a supply, equal to that now dispensed, for about 20 millions of years. This period, it will be observed, includes the entire physical history of the solar system, from Neptune down to Mercury. It must be liable however, to considerable uncertainty, as it assumes the radiation of heat to have been uniform.

Before attempting a comparison between the ages of the sun and certain of the fixed stars it should be premised that from the epoch of incipient solidification, or rather of incipient transition from the gaseous to the liquid form, the quantity of motion in the contracting mass, and consequently the amount of radiant heat, must gradually diminish. Many of the nebulæ and some of the fixed stars have not reached this epoch ; while the sun, 61 Cygni, and the companion of Sirius, as will be shown hereafter, have probably passed it. Our first comparison will be that of

The Sun and Alpha Centauri.

The larger component of the double star Alpha Centauri is of the first magnitude ; the smaller one, of the second. The color of both has been described as dark orange. According to Hind,* the system completes a revolution about its centre of gravity in 85 years ; the mean distance between the components being 23.49 times the radius of the earth's orbit—somewhat greater than the distance of Uranus from the sun.

Of all the fixed stars whose distances have been measured, Alpha Centauri is the nearest to us. Its annual parallax is $\frac{928}{1000}$ths of a second, which corresponds to a distance 7336 times that of Neptune from the sun : —so completely isolated in space is our planetary system.

The apparent magnitude of Alpha Centauri is greater than that of any star in the Northern Hemisphere ; and of those South of the equator but visible in our latitude, Sirius alone surpasses it in splendor. Its mass is nearly the same with that of the sun ;† while the intrinsic light and heat of the system are nearly three times greater. It may be inferred from these facts that the sun has probably passed the epoch of greatest heat, and that it is farther advanced in its physical history, or, in other words, is an older star, than Alpha Centauri.

*Monthly Notices of the R. A. S. for January, 1877. These elements differ materially from those previously found.

† Hind's recent value is *greater* than the sun's mass; all former estimates *less*.

61 Cygni.

The annual parallax of 61 Cygni is $\frac{46}{100}$ths of a second, which corresponds to a distance 448,000 times that of the earth from the sun. The magnitudes of the components are $5\frac{1}{2}$ and 6; their distance from each other is 45 times the radius of the earth's orbit; their period, about 500 years; and the sum of their masses, rather more than one third of the sun's mass. They have the same color—a golden yellow.

The mass of the larger component of 61 Cygni may be taken at one fifth of the sun's mass. According to the estimate of Sir William Herschel the light of an average star of the first magnitude is 50 times that of a star of the fifth, or about 75 times that of the larger component of 61 Cygni. The intrinsic light of the principal member of Alpha Centauri being twice that of the sun and 75 times that of A, 61 Cygni, we obtain the following relations:

	Sun.	A. 61 Cygni.
Surface, (densities equal?).....................	3	1
Mass...	5	1
Intrinsic light......................................	$9\frac{1}{2}$	1.

These numbers seem to indicate that 61 Cygni is farther advanced than the sun in its physical history.

Sirius.

"It has been long acknowledged," says Humboldt, "that of all the brightest luminous fixed stars of heaven, Sirius takes the first and most important place, no less in a chronological point of view, than through its historical association with the earliest development of human civilization in the valley of the Nile." The recent discovery of its binary character, together with the determination of its parallax, mass, motion, and constituent elements, have greatly enhanced the interest with which this star is regarded by the scientific public. From the meridian altitudes of Sirius, as observed by Sir Thomas Maclear, at the Cape of Good Hope during the years 1836 and 1837, Dr. Gylden, of Pulkowa, has found its annual parallax to be $\frac{193}{1000}$ths of a second, which corresponds to a distance 1,068,700 times that of the sun from the earth. The light of this star is therefore 16 years in reaching us.

The orbit of this binary system has been computed by Dr. Auwers, who finds the period of revolution to be 49 years and 146 days; the semi-axis major, 37 times the distance of the earth from the sun; and the eccentricity, 0.6148,—somewhat greater than that of Fays's comet. The mass of the companion is half that of the principal star; or more accurately, the mass of Sirius is 13.76, and that of the telescopic star, 6.71, the mass of the sun being unity. According to the photometrical experiments of Sir John Herschel, the light received from Sirius exceeds that of Alpha Centauri in the ratio of 25 to 6. Comparing, therefore, the distances of the two stars, we find the intrinsic light of Sirius to be 93 times that of Alpha Centauri.

or 279 times that of the sun. The relative quantity of heat emitted by the different bodies may be assumed to have the same ratio.

But while the mass and distance of Sirius have been ascertained within moderate limits of error, the degree of its condensation, as compared with that of the sun, is still undetermined. On the hypothesis of equal density the light emitted from the sun would be but $\frac{1}{48}$ th part of that radiated from an equal portion of the star's surface. But, if equal areas of the two bodies afford equal quantities of light, then the volume of Sirius is 4661 times that of the sun, and the mean density of the latter is 333 times that of the former. It seems probable, therefore, that the principal component has still chiefly, if not entirely, a gaseous constitution.

As the light of Sirius, according to Sir John Herschel, is 324 times that of an average star of the sixth magnitude, and as the satellite discovered by Clarke is of the ninth or tenth magnitude, the light of the latter must be much less than one thousandth part of that received from the principal star. But according to Auwers the mass of the less component is equal to half that of the greater. Is it possible to explain these remarkable facts on the theory that the two bodies had a simultaneous origin in the same nebula, or has their present proximity resulted from the proper motions of two originally independent stars?

The conclusions apparently sustained by the facts here considered may be summarized as follows:

(1.) The history of the solar system is comprised within twenty or thirty millions of years.

(2.) From the fact of the larger component of Alpha Centauri radiates twice as much light as the sun while the mass of the former is *less* than that of the latter, we infer the probability that our solar system is the more advanced in its physical history.

(3.) 61 Cygni seems to have reached a greater degree of condensation than the sun, since, on the hypothesis of equal density, the surface of the larger member is one third that of the sun, while the intrinsic light is less than one ninth.

(4.) The companion of Sirius appears to have reached a stage of greater maturity than the sun, while the contrary seems to be true in regard to the principal star.

BLOOMINGTON, INDIANA, March 26, 1877.